Procedures for Modelling TRACE-P Estimates

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ABSTRACT

TRACE-P, Total Risk Assessing Cost Estimate for Production, is intended as a contingency-funding vehicle for the first three years of production of designated systems. TRACE-P extends the TRACE concept of RDTE to Production, and serves to quantify risks in terms of their cost impact on designated systems. A mechanism is proposed here for generating such risk costs. It extends the use and application of the contractor's Work Breakdown Structure (WBS) in identifying risk prone areas, and combines the WBS with probabilistic networking techniques to create a data structure which generates risk costs for the designated program.

PURPOSE

The purpose of this paper is to show how the Venture Evaluation and Review Technique (VERT) networking model can be combined with the contractor Work Breakdown Structure in a way that provides the Program Manager with a powerful tool in determining potential risk costs to his program.

INTRODUCTION

TRACE-P, Total Risk Assessing Cost Estimate for Production, is intended as a contingency-funding vehicle for the first three years of production of designated systems. TRACE-P continues the TRACE concept of RDTE, and serves to quantify risks in terms of their cost impact on designated systems. The proposed mechanism for generating such risk costs involves no new reporting format. In fact, it merely extends the use and application of an existing reporting vehicle, the contractor's Work Breakdown Structure (WBS). The reasons for using the WBS are plain:

1. Virtually all risk-prone activities are performed by the contractor, not Government. Government is responsible for managing programs with risk; contractors encounter risk in actual execution of these programs.

2. The WBS hierarchy is a very convenient format to use in identifying those contractor activities which are more risk-prone than others. Thus, use of documents such as the contractor's Production Plan, Development Test/Operational Test reports, Production Readiness Reviews, Technical Data Packages, etc. in conjunction with the WBS will allow simple identification of risk prone areas.

The WBS is seen to be a powerful means of isolating risk to those pertinent work areas. However, the WBS in and of itself provides an incomplete picture of any contractual effort. This is because although the WBS shows the hierarchial organization of tasks, it does not show the manner in which these tasks are executed, nor the relation of the tasks to each other from a schedule network perspective. The full potential of the WBS as an analytical tool is therefore limited if we restrict our use of it to its hierarchial form.

POLICY CONSIDERATIONS FOR THE WBS

At present, the contractor's WBS is used by the government as the basis for tracking contractor cost and performance. In fact, Cost/Schedule Control Systems Criteria (C/SCSC) reporting is essentially one of the few uses to which the CWBS is applied in project management. In many instances, an examination of contractor schedules show that activities and milestones often relate to Contractor Data Requirements List items more than they do to the WBS. This lack of correlation can lead to needless confusion. Further, because schedule information does not track with the WBS, any projections addressing schedule or cost uncertainty will of necessity come from two diverse sources - the contractor's schedule and the WBS work packages, respectively. What is needed is a means of tying cost and schedule considerations together, and this objective can be readily obtained by a change in the use of the contractor's WBS and schedule network data.

It is proposed that contractors be required to submit schedule network diagrams of their activities and milestones so that the following minimum criteria are met:

(1) Each WBS element corresponds to one arc at an appropriate level. The coarsest level of detail should be level 3, and where specified by the government, should be 4 or lower if finer detail is required.

(2) For each arc, the contractor must provide its expected cost and duration, with all costs expressed in common units and all times expressed in common units. The expected cost should be readily available because in most cases that will correspond to the value of some work package.

(3) The network should be structured so that time phasing of activities and milestones will be readily apparent; the interrelationships between activities and milestones (i.e., network logic) also should be readily apparent.

(4) Activities which cannot be included as part of the WBS but which do affect time and cost must be included in the network.

(5) The network must span a period of time covering contract award to last delivery, and the sum of the costs for all arcs in the network must equal the contract cost or appropriate financial measure.

A few comments are in order here. First, the use of the WBS as the basis for a schedule network to be submitted by the contractor is certainly achievable. The imposition of such a requirement on him should not be any great hardship, because such information must already be at hand. For example, the contractor must know how his work is organized and he must have a fairly good idea of how much time and money each piece of the work will require. From the government perspective this is a very reasonable expectation. However, we must next consider the contractor's concerns. Often the WBS is devised in such a way that it simply does not make sense to use the WBS for presenting schedule data. Consequently, the contractor is forced to present schedule data in a manner different from the WBS. If the method proposed here is to work, government managers must choose and devise WBS elements in such a way that their portrayal in schedule format becomes feasible. One way this can be accomplished is if the WBS is not strictly bound to the hardware/software configuration of a system and its corresponding subsystems. If instead the WBS is portrayed to have as its subelements the activities associated with any particular subsystem, then it will be a simple matter for the contractor to provide the WBS-derived schedule. For example, if a piece of electronics equipment were to be developed, the WBS for that equipment might include subelements headed "Design", "Breadboard", "Test". In this way all WBS elements will be included in the schedule network. It is again stressed that if this concept is to work, government and contractual management alike are going to have to view the WBS as a vehicle for other than CSSRs, CPRs and the like. The WBS concept in the presently proposed form is expanded to provide total contract and, therefore, total project representation in a manner which unifies cost and schedule considerations. That is why the policy regarding the use of the WBS as well as the means of reporting schedule and cost needs to be reviewed and changed. Only then will the benefits that the remainder of this report discusses be realized. Extending the use of the WBS will as a minimum provide the government with a data base for its TRACE-P analyses.

THE WBS DATA BASE AND VERT

Many current tools of generating risk costs involve analysis of the WBS in its tabular form, or at best a bar chart schedule which lists each activity in a more or less standalone fashion. The Venture Evaluation Review Technique (VERT) eliminates these deficiencies by allowing program activities to be linked together in a symbolic network which is then probabilistically exercised for many (several hundred) iterations, dynamically testing program activities and their interfaces. Unlike other networking techniques which have fixed input data, VERT allows for functional relationships to be defined, i.e., the cost of one activity may be a function of the time-or manpower-loading of that activity, or of other related activities. This allows a more realistic modelling to be conducted of the contactor's work, thereby providing a refined measure of the associated risk costs compared to other analytical tools. The only additional requirement that use of the VERT techniques would impose on contractor personnel is that they provide WBS schedule data in network form, similar to PERT-type diagrams. We repeat our assertion that these data should be readily available from the contractor because the various cost account managers have to know how they are spending money on the work being performed. Once the data are provided to the Government in this format, the Government analyst can structure the VERT network and conduct the necessary activities needed in preparing the numerical data to be exercised by the network logic. VERT would then generate histogram data on cost and time which would predict the contractor's performance based on the input data.

SAMPLE CASE TRACE-P USING VERT

To illustrate the application of these procedures to generating TRACE-P estimates, we consider the hypothetical System X whose WBS and production schedule are shown in Figure 1. System X has four major subsystems which are produced in parallel, and then integrated and tested before delivered to the government. In the past, a TRACE-P estimate for System X would have been generated by having personnel with appropriate expertise examine each WBS element or else each risk element, and quantify the risk for each element in the form of a numeri-

System X

WBS (Down to Level 1 Only)

X

XA

XB

XC

XD

Typical Schedule

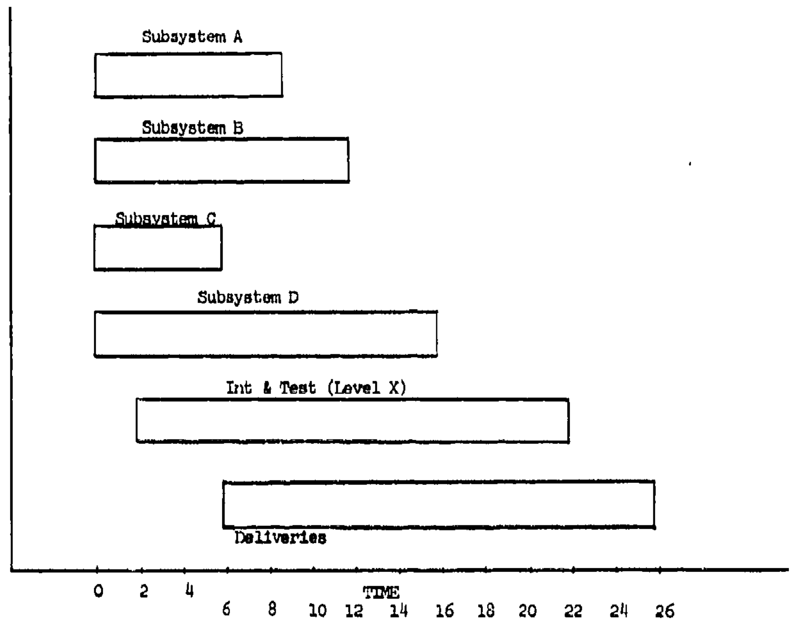


Figure 1.

cal multiplier. For example, if element XA costs $1 and it is determined that a risk multiplier of 1.25 is appropriate for XA, then XA's contribution to the TRACE-P is $1.25. The full TRACE-P would be the sum of all such products. In this manner, each element contributes its portion to the TRACE-P in the form of a point estimate; the TRACE-P for System X is also a point estimate which is the sum of the point estimates for each WBS element. So although the risk factor method is useful in identifying risk areas and their contributions to TRACE-P, nevertheless the outcome of this type of approach is one number, a point estimate.

In the method proposed here, the contractor would provide the Government schedule information on the WBS in the network form of Figure 2. Each arc in the network corresponds to an element of the WBS, and therefore the associated cost with that element can be readily provided by the contractor. Uncertainties in cost and schedule can now be examined in the light of this network representation; for example, in the network for Systems X's WBS, integration and test cannot begin until after unit #1 for each subsystem has been fabricated; this in turn affects the start of production deliveries. If there is a stretchout in the production schedule, the cost associated with that affected portion of the schedule can be modelled in VERT as a function of time, and the spread in time values will provide a more

System X WBS Network

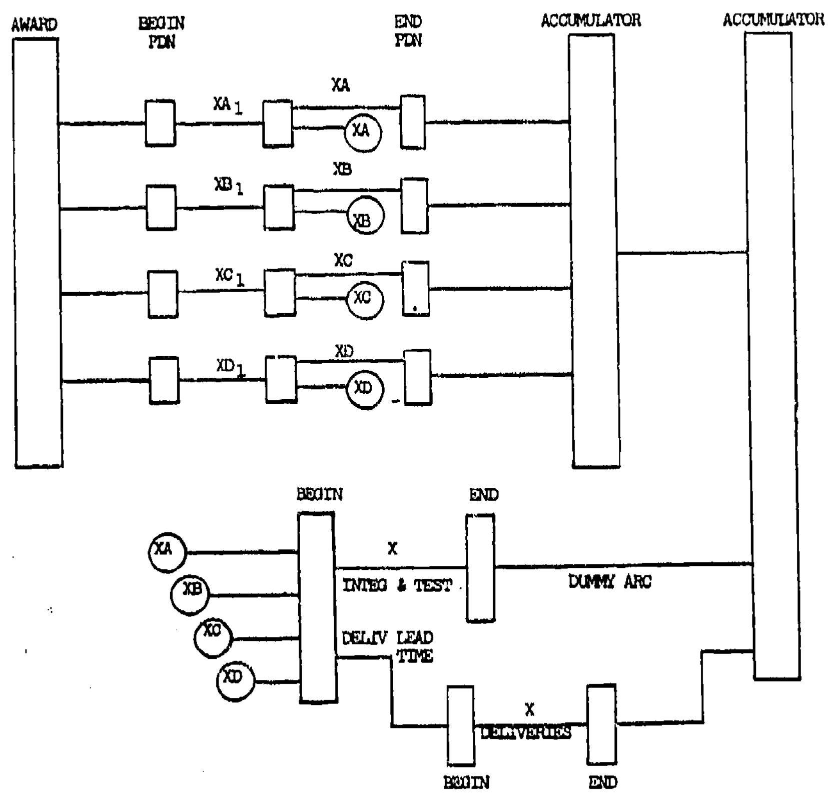


Figure 2.

deterministic basis for the TRACE-P generated. The spreads in time and cost can be determined by consultation with Government technical and contractual experts familiar with the WBS element under scrutiny. The analyst can incorporate this information in the VERT data base, and then by exercising the WBS network with VERT, a measure of System X's TRACE-P costs can be obtained.

Table 1 is a list of hypothetical input values for time and cost that VERT would use in simulating System X's project. The time parameters are given in a form suited to the use of the triangular probability density distribution; however, VERT permits the use of many distributions, and if another distribution were more applicable for modelling time, such as the exponential,, normal or binomial, the data applicable to their use could be easily formatted for execution by VERT. Regardless of the distribution used, the data would have been obtained from detailed conversations with area specialists so as to assure inclusion of their expert opinions in forming the VERT data base. The same would also apply to the costs being modelled.

Cost distributions are the central issue when it comes to discussing TRACE-P, and for the WBS elements of System X, it was decided to choose their representative costs as being linear functions of the time required to complete each activity, thereby illustrating the great flexibility of the VERT system in generating TRACE-P figures. To further clarify, consider

System X WBS Network
Input Data

		TIME		
		MIN	MOST LIKELY	MAX
X(INIT + TEST)		20.0	20.0	24.0
X(DELIV LEAD TIME)		4.0	4.0	4.0
X(DELIVERIES)		20.0	20.0	22.0
XA_1	1st PDN UNIT	1.0	1.0	2.0
XB_1		2.0	2.0	4.0
XC_1		1.0	1.0	2.0
XD_1		3.0	3.0	4.0
XA	PDN UNITS 2-END	8.0	8.0	10.0
XB		10.0	10.0	12.0
XC		5.0	5.0	6.0
XD		13.0	13.0	15.0

		COST
X(INT + TEST)		$500 + 100\ [(T_{XB_1}-2) + (T_X-20)]$
XA_1	1st PDN UNIT	$100 + 200\ (T_{XA_1}-1)$
XB_1		$100 + 250\ (T_{XB_1}-2)$
XC_1		$100 + 100\ (T_{XC_1}-1)$
XD_1		$250 + 150\ (T_{XD_1}-3)$
XA	PDN UNITS 2-END	$900 + 200\ (T_{XA}-8)$
XB		$900 + 250\ (T_{XB}-10)$
XC		$500 + 100\ (T_{XC}-5)$
XD		$750 + 150\ (T_{XD}-13)$

Table 1.

the cost expression for the first unit production of subsystem A. The expression is:

$$C = 100 + 200\ (T_{XA_1}-1).$$

The time data for subsystem A indicates a most likely and also a minimum requirement of 1 month to produce the first unit before it is sent forward for integration and test. The cost relationship here is structured in such a way that if the time required to produce subsystem A's first unit exceeds 1 month, a penalty of \$200K times the excess measured in months exceeding 1 month will be incurred. This would correspond to a real world situation where the contractor would need to hire many highly skilled workers, or make additional capital investments to assure minimal schedule slippage. However, if there is no slippage, no cost penalty is incurred. Each subsystem has its own cost penalty. As VERT exercises the System X WBS network, random time values for the respective WBS subelements are incurred for each iteration of VERT, thereby generating different cost penalties.

If the contractor were 100% certain of meeting his schedule, there would be no variability in time and hence no cost penalties. The total contractual cost would be \$4100K, which is the sum of the constant parts of all the WBS subelement costs in Table 1. However, there is schedule uncertainty, which is reflected in the fact that the time data for each subelement of System X is described by a probability distribution. This in turn causes various cost penalties to be incurred for each iteration of the

System X network by VERT. After the number of iterations is completed, VERT will generate histograms of cost data - by sequential time period and for the program's full duration - which the Program manager/analyst may use in selecting an appropriate risk level for TRACE-P funding. Figures 3-6 are histograms generated by VERT for months 0-12, 12-24, 24-36, and 0-36 of the program, providing the PM with anticipated yearly costs as well as anticipated program costs. If, for example, the Program Manager of System X wishes to be conservative during the first year of the program, he might pick the 90% point of the histogram for months 0-12. This can be found by interpolating the cumulative distribution function values, which bracket the 90% point, and comes out to $4404K for year 1. The meaning of this choice is simply, that of all the cost values generated by VERT for year 1 of System X, the value $4404K was exceeded only for 10% of those iterations, and therefore, it exceeded 90% of the cost values generated for that year. By selecting a large number of iterations we can be statistically confident that costs will fall within this arena, providing we have an accurate representation of subelement costs and schedules. Use of the WBS helps to assure this aspect of getting an accurate handle on TRACE-P.

Analagous choices of percentile points can be made for years 2 and 3 of System X. In this manner, the risk funding level may be lowered for years 2 and 3 if the PM feels such actions are warranted. The overall program risk funding level may be found by summing costs for years 1, 2 and 3 and reading the value obtained off the overall program cost histogram, Figure 6. To again illustrate, the 90% point for year 1 was found to be $4404K. For year 2 (months 12-24), let us read directly off the histogram. The 81.8% point is $941K, and let us suppose the PM is satisfied with this figure, i.e., of the cost generated by VERT for year 2, they did not exceed $941K for 81.8% of the total iterations. For year 3, suppose the PM selected the 73.3% point which reads as $56K. The sum of these 3 figures, 4404 + 941 + 56, is $5401K, and this corresponds to an overall program risk funding level of about 90%, as shown in Figure 6. That is to say, in order to be 90% confident that System X's contractor costs will not exceed his budget, the PM would need to have on hand $5401K, or 31.7% above the initial projected cost of $4100K. Whether or not such a contingency funding level is appropriate for a system entering production will not be discussed here. The example chosen had purposely built-in severe cost penalties to illustrate the nature of TRACE-P issues. If the PM wished to be less conservative in this example, he might be willing to go for a 70% confidence level. The new total cost as read from Figure 6 would then be $5190K, or 26.6% above the contract budget. The TRACE-P deferral for the 3 years would be $1090K ($5190K - 4100K). The PM could then allocate the TRACE-P deferral among each program year, verifying that when the deferral is added to the baseline for all three years, they sum up to the $5190K. Whatever course is taken, the WBS network approach permits the PM to make difficult decisions with more useful information at his disposal. With cost becoming an increasingly scrutinized arena, the VERT-WBS methodology for generating TRACE-P estimates cannot be ignored.

```
POSITIVE COST INCURRED BETWEEN THE TIME PERIODS OF      0.0  -      12.00

            CFD  0.1  0.2  0.3  0.4  0.5  0.6  0.7  0.8  0.9  1.0
  3823.2524 I----I----I----I----I----I----I----I----I----I----I MIN
            I                                                  0.0
  3823.2524 I
            I*                                                 0.012
  3863.0930 I
            I*                                                 0.018
  3902.9336 I
            I**                                                0.046
  3942.7742 I
            I****                                              0.078
  3982.6147 I
            I*******                                           0.132
  4022.4553 I
            I**********                                        0.200
  4062.2959 I
            I*************                                     0.258
  4102.1328 I
            I******************                                0.354
  4141.9727 I
            I***********************                           0.470
  4181.8125 I
            I****************************                      0.568
  4221.6523 I
            I*********************************                 0.654
  4261.4922 I
            I**************************************            0.754
  4301.3320 I
            I*****************************************         0.828
  4341.1719 I
            I********************************************      0.876
  4381.0117 I
            I**********************************************    0.918
  4420.8516 I
            I***********************************************   0.940
  4460.6914 I
            I************************************************  0.966
  4500.5312 I
            I************************************************* 0.980
  4540.3711 I
            I**************************************************0.992
  4580.2109 I
            I**************************************************0.996
  4620.0508 I
            I**************************************************0.998
  4659.8906 I
            I**************************************************1.000
  4699.7461 I
            I**************************************************1.000
  4699.7461 I----I----I----I----I----I----I----I----I----I----I MAX

            NO OBS-----------      500  STD ERROR-        155.6463
            COEF OF VARIATION-    0.04  MEAN------       4200.5117
            KURTOSIS (BETA 2)-    2.83  MEDIAN----       4196.2227
            PEARSONIAN SKEW---    0.24  MODE------       4162.9375
```

FIGURE 3

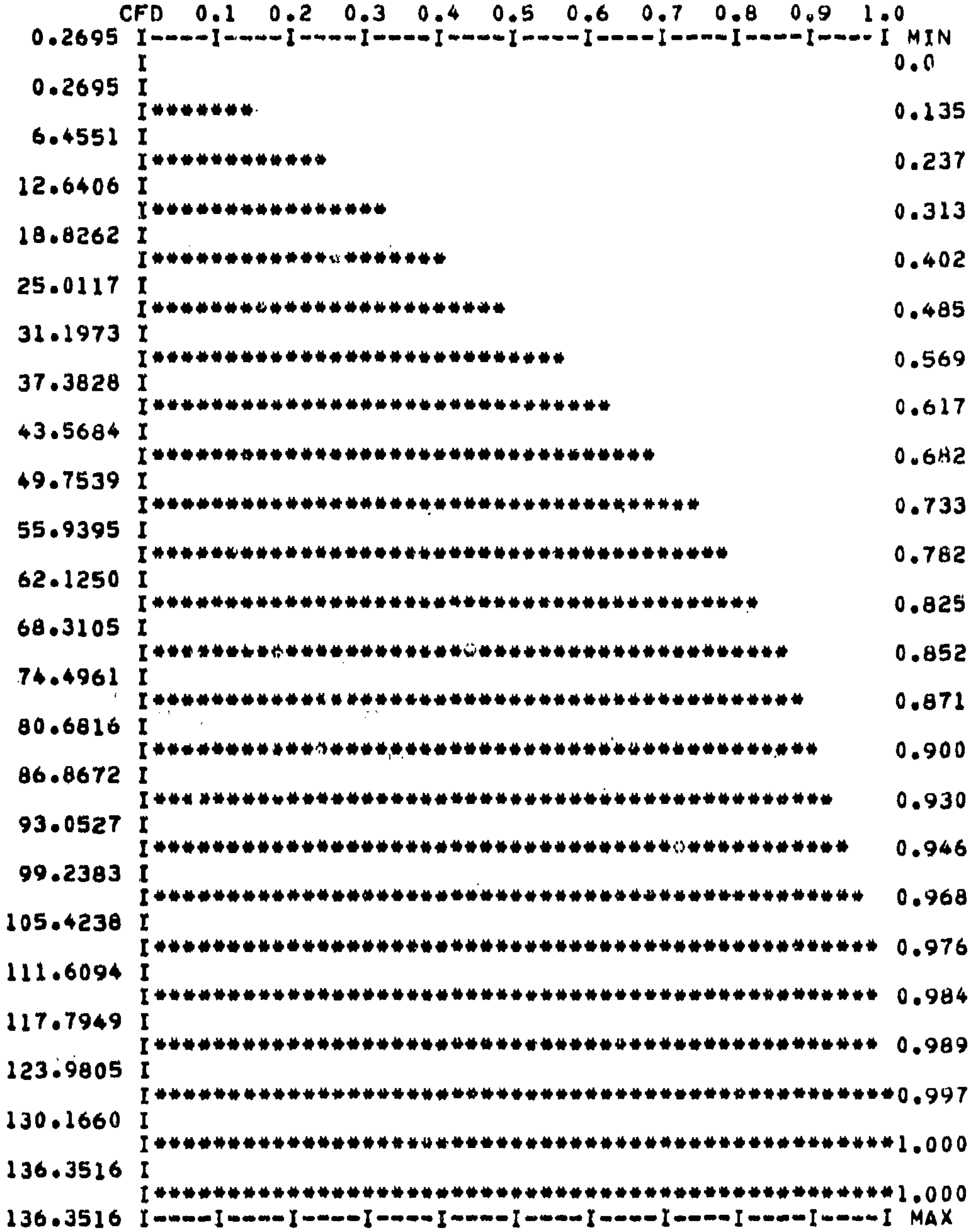
POSITIVE COST INCURRED BETWEEN THE TIME PERIODS OF   12.00 -   24.00

```
                CFD  0.1  0.2  0.3  0.4  0.5  0.6  0.7  0.8  0.9  1.0
     589.7739 I----I----I----I----I----I----I----I----I----I----I MIN
              I                                                    0.0
     589.7739 I
              I*                                                   0.012
     616.8157 I
              I*                                                   0.020
     643.8574 I
              I**                                                  0.050
     670.8992 I
              I****                                                0.088
     697.9409 I
              I*******                                             0.148
     724.9827 I
              I***********                                         0.226
     752.0244 I
              I****************                                    0.318
     779.0662 I
              I*********************                               0.426
     806.1079 I
              I*************************                           0.496
     833.1497 I
              I******************************                      0.600
     860.1914 I
              I**********************************                  0.688
     887.2332 I
              I**************************************              0.766
     914.2749 I
              I*****************************************           0.818
     941.3167 I
              I********************************************        0.880
     968.3584 I
              I**********************************************      0.912
     995.4001 I
              I**********************************************      0.928
    1022.4419 I
              I***********************************************     0.948
    1049.4836 I
              I************************************************    0.964
    1076.5254 I
              I*************************************************   0.982
    1103.5671 I
              I**************************************************0.998
    1130.6089 I
              I**************************************************0.998
    1157.6506 I
              I**************************************************1.000
    1184.6953 I
              I**************************************************1.000
    1184.6953 I----I----I----I----I----I----I----I----I----I----I MAX

              NO OBS-----------      500   STD ERROR-       111.3275
              COEF OF VARIATION-    0.13   MEAN------       839.4507
              KURTOSIS (BETA 2)-    2.88   MEDIAN----       834.1758
              PEARSONIAN SKEW---    0.47   MODE------       787.0784
```

FIGURE 4

POSITIVE COST INCURRED BETWEEN THE TIME PERIODS OF 24.00 - 36.00



NO OBS-----------	371	STD ERROR-	30.8206
COEF OF VARIATION-	0.79	MEAN------	39.2381
KURTOSIS (BETA 2)-	2.94	MEDIAN----	33.1992
PEARSONIAN SKEW---	1.10	MODE------	5.2579

FIGURE 5

POSITIVE COST INCURRED BETWEEN THE TIME PERIODS OF   0.0 -   36.00

```
                 CFD  0.1  0.2  0.3  0.4  0.5  0.6  0.7  0.8  0.9  1.0
        4419.7148 I----I----I----I----I----I----I----I----I----I----I MIN
                  I                                                   0.0
        4419.7148 I
                  I                                                   0.002
        4486.7969 I
                  I*                                                  0.012
        4553.8789 I
                  I*                                                  0.030
        4620.9609 I
                  I***                                                0.062
        4688.0430 I
                  I*****                                              0.098
        4755.1250 I
                  I********                                           0.154
        4822.2070 I
                  I*************                                      0.250
        4889.2891 I
                  I******************                                 0.350
        4956.3711 I
                  I***********************                            0.462
        5023.4531 I
                  I****************************                       0.562
        5090.5352 I
                  I*********************************                  0.656
        5157.6172 I
                  I*************************************              0.744
        5224.6992 I
                  I****************************************           0.808
        5291.7812 I
                  I********************************************       0.876
        5358.8633 I
                  I**********************************************     0.912
        5425.9453 I
                  I***********************************************    0.940
        5493.0273 I
                  I************************************************   0.956
        5560.1094 I
                  I************************************************   0.970
        5627.1914 I
                  I*************************************************  0.978
        5694.2734 I
                  I**************************************************0.996
        5761.3555 I
                  I**************************************************0.998
        5828.4375 I
                  I**************************************************1.000
        5895.5234 I
                  I**************************************************1.000
        5895.5234 I----I----I----I----I----I----I----I----I----I----I MAX

                  NO OBS------------       500   STD ERROR-       255.8068
                  COEF OF VARIATION-      0.05   MEAN------      5069.0469
                  KURTOSIS (BETA 2)-      3.02   MEDIAN----      5045.9609
                  PEARSONIAN SKEW---      0.31   MODE------      4989.9102
```

FIGURE 6